A comparison of the shaping characteristics of two nickel–titanium endodontic hand instruments

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Abstract

Dobó-Nagy C, Serbán T, Szabó J, Nagy G, Madléna M. A comparison of the shaping characteristics of two nickel–titanium endodontic hand instruments. *International Endodontic Journal*, **35**, 283–288, 2002.

Aim The purpose of this study was to compare the shaping characteristics of Ni–Ti K-files and Ni–Ti S-files manipulated by hand.

Methodology A total of 60 extracted human roots were embedded in resin blocks. The embedded roots were divided into three groups: (i) roots with straight; (ii) apically curved; and (iii) continuously curved canals. Each of the three groups was randomly divided into two subgroups; one subgroup in each group was prepared with Ni–Ti K-files and the other with Ni–Ti S-files. The files were used with a step-back technique and enlarged so that the master apical file was size 30, and the canals were stepped back to size 40. The performance of the files was assessed by the superimposition of projected radiographs taken in bucco-lingual and mesio-distal directions before and after the preparation. The results were analysed statistically using analysis of covariance and Duncan's multiple range test.

Results Although canal preparation using Ni–Ti K-files was quicker, there were no statistically significant differences between file types. The Ni–Ti S-file removed significantly more material at the most coronal level ($P < 0.05$). There were minor differences between instruments at the apical level. Only in the proximal view of apically curved canals prepared with Ni–Ti S-files was significantly more dentine removed from the outer aspect of the curvature ($P < 0.05$). At the middle level (wide danger zone) the Ni–Ti S-files removed more dentine from the inner aspect of the curvature in those roots with apically curved canals.

Conclusions Under the conditions of this study, preparation with Ni–Ti K-files produced more appropriate shapes in roots with apically curved canals than Ni–Ti S-files.

Keywords: canal shaping, hand files, nickel–titanium, root canals.

Received 28 July 2000; accepted 14 June 2001

Introduction

Cleaning and shaping of root canals is the most important aspect of root canal treatment. Over the years, a number of instruments have been developed for shaping canals. In previous studies (Dobó-Nagy *et al.* 1997a,b), statistically significant differences were found when comparing the shaping ability of stainless steel K-files and K-Flex files. Post-instrumentation shape of curved canals was superior when prepared with flexible stainless steel instruments than with conventional files (Briseno & Sonnabend 1991, Al-Omari *et al.* 1992). However, increasing the flexibility of endodontic instruments through the use of Ni–Ti alloy has not always resulted in better shaping ability (Gambill *et al.* 1996, Harlan *et al.* 1996, Elliott *et al.* 1998, Carvalho *et al.* 1999).

The Ni–Ti S hand file is made by grinding a circular tapered blank into a double helix fluted pattern. The helical angle is closer to an H-file than a K-file and this may explain the improved cutting efficacy of S-files in linear motion (Schafer 1997). Shaping ability of stainless steel files was tested in resin blocks (Briseno & Sonnabend 1991) but no statistically significant differences between

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the nine instruments were found. However, when taking the ideal values as reference points, statistical differences were found in canals enlarged with S-files at all the three measured levels. In addition, the S-file provided poorer results compared with the H-file at the apical level (1 mm coronally from the end-point) and at the third measured point (11.5 mm coronally). The S-file showed an increased tendency to transport root canals toward the convex side at the apical level and toward the concave side at the middle level, when compared to stainless steel, a K-file or a K-Flex file. To date, no investigation of the shaping quality of Ni–Ti S hand files has been reported.

The aim of this study was to compare the shaping characteristics of the two nickel–titanium instruments in extracted human root canals.

Materials and methods

A total of 153 extracted human teeth with a single canal and patent apical foramen were selected. The specimens had been stored in phosphate buffer saline solution (pH 7.2) containing sodium azide 0.2% at 4°C. Each root was embedded in a $15 \times 15 \times 20$ mm resin block. Access cavities were cut just into the dentine using a high-speed bur. The roof of the pulp chamber was then removed with a slowly rotating round bur. Following pulp extirpation, the root canals were filled with a radiopaque mixture of Lipiodol Ultra-Fluid (Byk, Konstanz, Germany) and Micropaque HD Oral (Guerbet, Schultzbach, Germany) by centrifuging at 1200 g for 30 s. An initial size 15 apical file (IAF) was inserted into the canals and digitized radiographs (RVG, Trophy Radiologie, Paris, France) were taken from bucco-lingual (b-l) and mesio-distal (m-d) directions using a paralleling technique (Forsberg 1992). Dilacerated, bayonet-shaped and extremely narrow canals that could not be penetrated by a file size 10 were excluded. Roots were divided into three groups on the basis of their radiographic images using computer-graphic software (Dobó-Nagy *et al.* 1995). The roots were grouped according to canal shape, namely: straight (I-form), apically curved (J-form) and continuously curved (C-form). Each group (containing 20 roots) was divided randomly into two equal subgroups for preparation using one of the following two instrument types: (i) Ni–Ti K-file (Beutelrock, München, Germany); (ii) Ni–Ti S-file (Sendoline, Kista, Sweden). Root canal enlargement was carried out randomly by two operators with considerable experience in root canal preparation. The process was carried out with purely tactile sensation, however, the working length and the b-l and m-d configuration of each canal was always available to the operator. The root length was modified by sectioning the coronal end in order to obtain a working length of 18 ± 2 mm. Apical limit was determined 1 mm coronal to the radiographic apex. Files were used in a push–pull motion around the entire circumference of the canal. The step-back preparation technique was adopted for both instruments (Mullaney 1979). Preflaring of orifices was not carried out. The IAF was size 15, the master apical size was 30 and the root canal flared using a size 40 file. Copious irrigation with 10 mL distilled water was used throughout the preparation and was introduced with a 27-gauge needle and a syringe. Two postoperative radiographs were taken of each root using radiovisiography as described previously.

Canal defects

The apical limit of the root canal preparation located within 1 mm of the radiographic apex was termed the *apical stop*. The creation of a false channel that exited the root surface during instrumentation at a point other than the anatomic apical foramen was termed a *perforation*. A *zip* was defined as an irregular and excessive widening of the canal close to the end-point of the preparation. The narrowest level of the apical third of the canal associated with zip which occurred more toward the orifice was termed the *elbow*. In the middle part of the canal, excessive removal of dentine from the inner aspect of canal curves was termed the *danger zone*. Coronal movement of the apical stop and loss of working length due to a build-up of dentine mud was termed a *blockage*.

Assessment of canal preparation

The time taken to prepare each canal was recorded in min and s. It included the preparation, as well as changing files, and irrigation time.

Superimposed, standardized 1 : 10 projections of the original canal and the prepared canal in mesio-distal and bucco-lingual directions were used to evaluate the difference in shape between pre- and postoperative canals. Accurate location and superimposition of the radiographs in both views was facilitated by the presence of two metal markers placed at the corners of one side of each resin block.

The prevalence of perforations, blockages, zip and elbow formation were noted. The amount of dentine removed at the most coronal level of the canal was determined and the surface area at this level obtained by calculating the area of an ellipse (πab). Lateral projections of the elliptic surface were gained by the two directional

radiographs. The radii of the ellipse (a and b) were determined by dividing the measured diameters of the canal at this level of the two views (b-l and m-d), respectively.

Canal transportation was expressed by the maximum asymmetry of preparation. The maximum asymmetry of preparation at the apical level and at the danger zone of the root canals was measured on the inner concave and the outer convex sides. Measurements were carried out perpendicular to the axis of the original canal using the method of Dobó-Nagy *et al.* (1997b). The original canal width was divided into two halves, thus defining a point of the canal axis which served as a reference point for the measurement of asymmetry. Asymmetry (expressed as an absolute value) was calculated by subtracting the left from the right prepared canal contour distances from the reference point.

Statistical analysis

Analysis of covariance was used to compare the preparation time, the amount of removed material at the most coronal part of canals and root canal form groups. Duncan's multiple range test was used for statistical analysis of the asymmetry of preparation values. Significant differences were noted at $P < 0.05$ level.

Results

Procedural accidents

No perforations occurred in the canals of any groups.

Coronal movement of the apical stop was not dependent on the instrument type but it was more frequently observed in curved canals. In canals prepared with Ni–Ti S-files two straight, four J-form and four C-form canals were affected. In the Ni–Ti K-file group two straight, four J-form and two C-form canals had reduced working length following instrumentation. The mean distance between the apical stop and apex was 0.34 mm in the Ni–Ti K-file group and 0.32 mm in the Ni–Ti S-file group; this difference was not significant.

Zips and elbows

The prevalence of zips and elbows was 26.6% in both groups. The mean width of the elbow was 0.36 mm. The mean elbow to root apex distance was 1.68 mm. In the Ni–Ti K-file group an elbow occurred in one of the straight canals, two of the J-forms and five of the C-form canals. In the Ni–Ti S-file group elbows were detected in two of the straight canals, five of the J-form and one of the C-form canals.

Preparation time

There was no statistically significant difference in preparation times between the instruments (Table 1).

Area change at the orifice

The results of area change measurements at the most coronal level are presented in Table 1. Statistical analysis revealed that Ni–Ti S-files removed significantly greater amounts of dentine compared to Ni–Ti K-files ($P < 0.05$). The analysis of covariance did not show any statistically significant relationships between the amount of removed dentine at the most coronal level and the preparation time.

Canal transportation at the apical level

Mean transportation values at the apical level are outlined in Figure 1. In the case of straight and C-form canals there were no significant difference between the two instruments. Significantly less transportation was obtained from the Ni–Ti K-file in J-form canals compared to Ni–Ti S-file in the same anatomical group ($P < 0.05$). Ni–Ti S-file produced less transportation on the C-form canals compared to the J-form canals, however, this difference was statistically significant only in the proximal view

Table 1 Mean preparation time (min) and area change (mm^2) at the most coronal level grouped by file and canal form

	File type					
	Ni–Ti S-file			Ni–Ti K-file		
	I	J	C	I	J	C
Preparation time	16.11	17.78	19.50	13.73	17.00	15.50
(SD)	(4.48)	(5.67)	(10.29)	(5.39)	(4.47)	(4.11)
Area change	1.63	1.39	1.98	1.12	1.14	1.14
(SD)	(0.82)	(1.03)	(1.32)	(0.62)	(0.84)	(0.93)

I, straight root canal; J, apically curved canal; C, continuously curved canal.

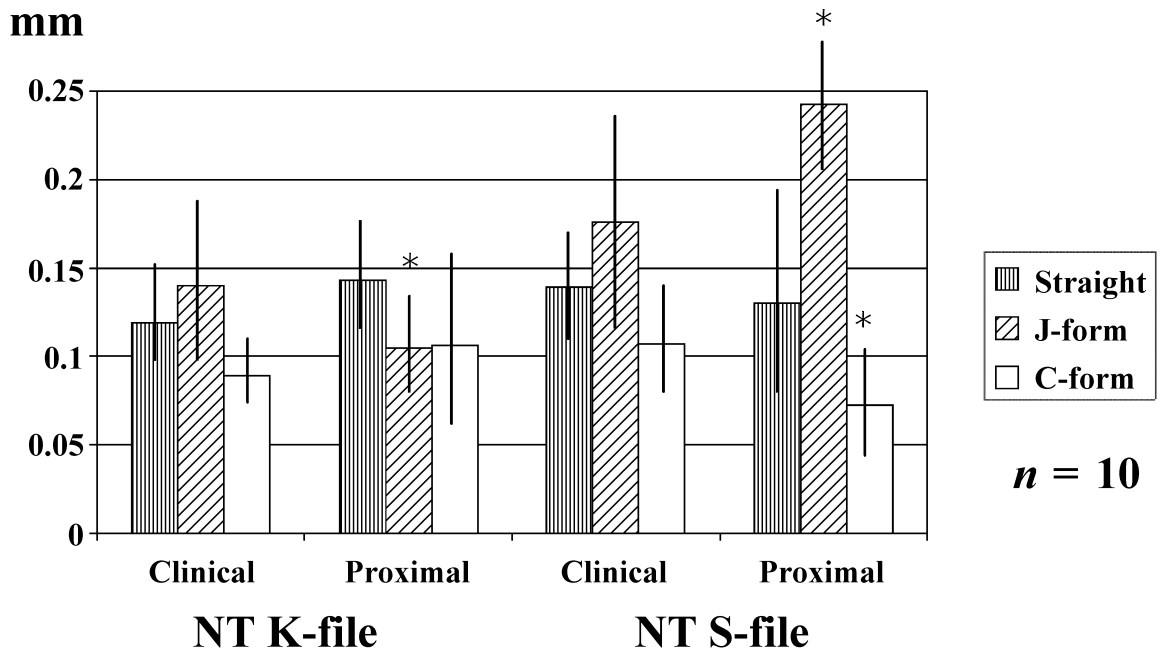

Figure 1 Mean preparation asymmetry values at the apical level representing both clinical and proximal views parameters. *Means significance at $P < 0.05$; bars represent standard deviation.

($P < 0.05$). The Ni–Ti K-files were not significantly different in the J-form and C-form groups.

Canal transportation at the middle third level

Results of transportation at the middle third level (danger zone) are presented in Figure 2. More transportation was found on J-form canals prepared by the Ni–Ti S-files in both views. Statistically significant differences ($P < 0.05$) were found between the Ni–Ti K-files and Ni–Ti S-files only in the proximal view of this form of canal. The least transportation was associated with the C-form canals instrumented by Ni–Ti S-files. This parameter was found to be significant ($P < 0.05$) between the J-form and C-form groups both in the clinical and proximal views when the preparation was made by Ni–Ti S-files.

Discussion

Comparison of the amount of removed dentine in conjunction with the preparation time represents the efficiency of an instrument. The S-files removed more dentine than the K-type files (Stenman & Spångberg 1990), possibly because the rake angle of the S-file is positive compared to the K-file (Schafer 1997). In this study, the preparation times tended to be shorter for Ni–Ti K-files compared to Ni–Ti S-files in all groups (Table 1). An explanation for this finding is the fact that the Ni–Ti S-files removed significantly more dentine at the most coronal level compared to the Ni–Ti K-files. The circumferential instrumentation of unflared canals requires substantial dentine removal at this level and the more effective the instrument the more dentine is removed at the most coronal level. This dentine removal resulted in a longer preparation time and increased fatigue for the operator.

Procedural accidents such as zip and elbow formation were observed in straight root canals. This surprising result may be explained by the morphology of human root canals. Roots grouped as 'straight' do actually have slightly curved canals (Dobó-Nagy *et al.* 1995). Our conception concerning the relatively high prevalence of procedural accidents in straight canals is discussed in our previous paper (Dobó-Nagy *et al.* 1997b). In the present study no significant differences were observed between the two instruments in terms of procedural accidents. However, semiquantitative methods for observing the prevalence of perforations, blockage or zip and elbow formation are not adequate for determining fine differences between instruments.

The preparation asymmetry measurement (Dobó-Nagy *et al.* 1997a,b) is a sensitive quantitative method for determining the transportation of root canals. Using this method the Ni–Ti S-file produced greater transportation at the apical as well as at the danger zone in J-form canals. The differences in transportation between the

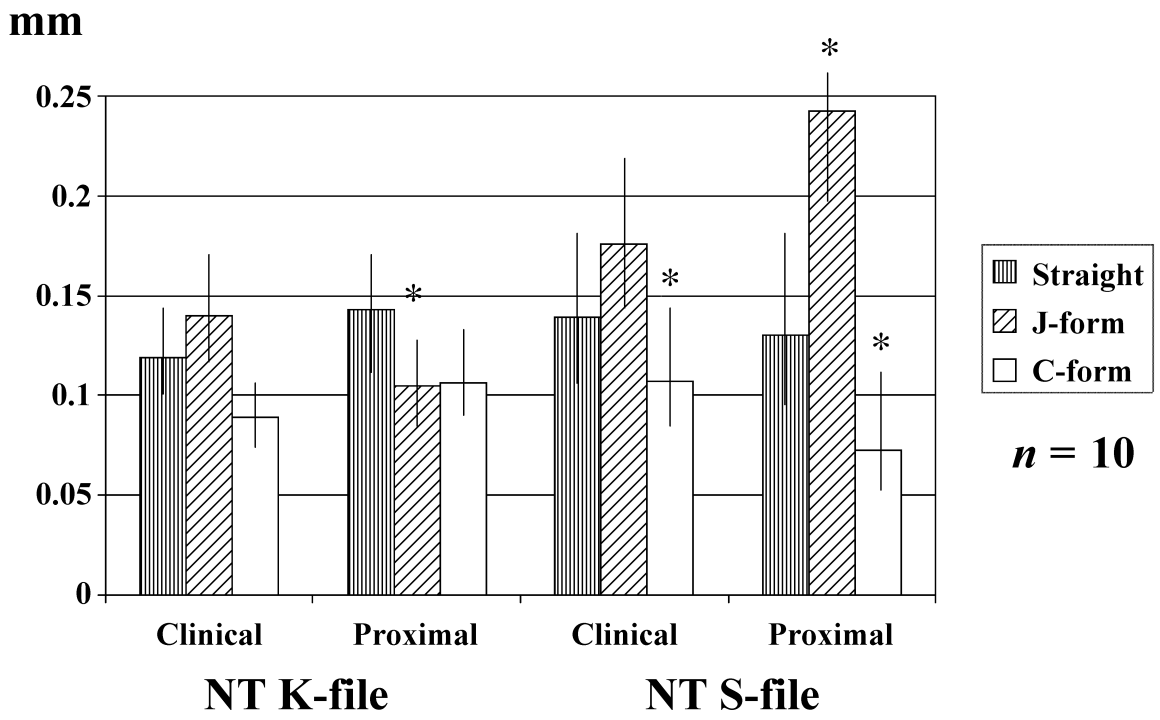

Figure 2 Mean asymmetry values at the 'danger' zone representing both clinical and proximal parameters. *Means significance at $P < 0.05$; bars represent standard deviation.

two instruments in the J-form canal group may be explained by the different designs of the two instruments. The positive rake angle combined with unbalanced preparation of Ni–Ti S-files delivered an increased hour-glass shape in abrupt curvatures. This implies that the Ni–Ti K-files should be chosen for abrupt curvatures in preference to Ni–Ti S-files. Comparison of transportation values according to root canal forms revealed a statistically significant difference between J- and C-form canals prepared with Ni–Ti S-files. This observation may be explained by the increased effectiveness of the Ni–Ti S-files in the coronal part of the canal. This simplified root canal form modified by the instrument itself delivered significantly better results in the C-form canal group prepared with Ni–Ti S-files.

Acknowledgements

This study was partly supported by the Hungarian Research Fund, OTKA grants T022455 and T029411.

References

Al-Omari MAO, Dummer PMH, Newcombe RG (1992) Comparison of six endodontic files to prepare simulated root canals. Part 1. *International Endodontic Journal* **25**, 57–66.

Briseno BM, Sonnabend E (1991) The influence of different root canal instruments on root canal preparation: an in vitro study. *International Endodontic Journal* **24**, 15–23.

Carvalho LAP, Bonetti I, Borges MAG (1999) A comparison of molar root canal preparation using stainless-steel and nickel–titanium instruments. *Journal of Endodontics* **25**, 807–10.

Dobó-Nagy C, Szabó J, Szabó J (1995) A mathematically based classification of root canal curvatures on natural human teeth. *Journal of Endodontics* **21**, 557–60.

Dobó-Nagy C, Bartha K, Bernáth M, Verdes E, Szabó J (1997a) A comparative study of seven instruments in shaping the root canal in vitro. *International Endodontic Journal* **30**, 124–32.

Dobó-Nagy C, Bartha K, Bernáth M, Verdes E, Szabó J (1997b) The effect of root canal morphology on canal shape following instrumentation using different techniques. *International Endodontic Journal* **30**, 133–40.

Elliott LM, Curtis RV, Pitt Ford TR (1998) Cutting pattern of nickel–titanium files using two preparation techniques. *Endodontics and Dental Traumatology* **14**, 10–5.

Forsberg J (1992) A method for experimental dental radiography. *International Endodontic Journal* **25**, 93–6.

Gambill JM, Alder M, del Rio CE (1996) Comparison of nickel–titanium and stainless steel hand-file instrumentation using computed tomography. *Journal of Endodontics* **22**, 369–75.

Harlan AL, Nicholls JI, Steiner JC (1996) A comparison of curved canal instrumentation using nickel–titanium or stainless steel files with the balanced-force technique. *Journal of Endodontics* **22**, 410–3.

Mullaney TP (1979) Instrumentation of finely curved canals. *Dental Clinics of North America* **23**, 575–92.

Schafer E (1997) Root canal instruments for manual use: a review. *Endodontics and Dental Traumatology* **13**, 51–64.

Stenmann E, Spångberg LSW (1990) Machining efficiency of endodontic K-files and Hedstrom files. *Journal of Endodontics* **16**, 375–82.

